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(19)

(54) CONTROLLED ENVIRONMENT APPARATUS AND PROCESS FOR PLANT HUSBANDRY

(71) We, ENVIRONMENT/ONE CORPORATION, a corporation organised and existing under the laws of the State of New York, United States of America of 2773 Balltown Road, city of Schenectady, Schenectady County, New York 12309, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

In 1949, a "phytotron" was opened at the Earhart Plant Research Laboratory at the California Institute of Technology, in Pasadena, California to study the growth of plants within a controlled environment. Since that time, similar types of controlled environment apparatus have been built primarily as research tools in the study of plant growth. These devices have controlled temperature, humidity, circulation, carbon dioxide, and light. The results obtained with such controls are quite startling, but the devices have not been suited for small operations, particularly use within the home.

The prior art devices of this type have been particularly cumbersome with respect to the complicated controls and expense of equipment. Further, they have required considerable maintenance and supervision. It is an object of the present invention to overcome these disadvantages so that an economical unit may be provided for small volume usage, particularly within the home and small volume experimental use.

According to this invention, apparatus for providing a controlled environment for plant husbandry includes a closable plant growing chamber; a separate control volume for a gas to be introduced into the growing chamber; pressure regulating means for regulating the pressure of the gas, which is to be supplied from a source of the gas at pressure higher than the pressure in the growing chamber, to an intermediate, predetermined pressure; and valve means operable to introduce the gas at said intermediate, predetermined pressure into the control volume so as to fill the control volume with a predetermined quantity of the gas and to discharge that predetermined quantity of the gas from the control volume into the growing chamber.

Since the growing chamber is of predetermined volume, the discharge of the predetermined quantity of the gas from the control volume into the growing chamber establishes a predetermined concentration of the gas in the growing chamber.

Conveniently the apparatus further includes a pressure gauge which measures said predetermined intermediate pressure, said pressure regulating means being adjustable to adjust said predetermined, intermediate pressure and said pressure gauge being calibrated to indicate the parts of the gas in the control volume per million parts of gas in the growing chamber.

The apparatus may still further include means for controlling the energising and de-energising of an electrically powered artificial light source for producing light within the growing chamber.

The apparatus may still further include circuit means for operating said valve means in response to said light controlling means being in a state de-energerising the light source to introduce said gas into said control volume and further operating said valve means in response to said light controlling means being in a state energising the light source for discharging said gas from said control volume into the growing chamber.

The apparatus may still further include a vent valve for admitting outside environment air into said growing chamber when open and having a closed position for effectively sealing said growing chamber from the outside environment air, and automatic actuator means which opens said vent valve in response to said valve means introducing said gas into said control volume and which closes said vent valve in response to said valve means discharging said gas into said growing chamber from said control volume.

Preferably, said actuator means includes a power cylinder means spring biased to close said vent valve and having a working chamber expansible by gas under pressure to open said vent valve, and said working chamber forms part of said control volume.

In the preferred form of the apparatus, a light chamber is provided for the artificial light source fluid separate from, but in light communication with, the growing chamber, and blower means is provided for circulating outside environment air through said light chamber when said vent valve is closed and for circulating outside environment air through said vent valve into said growing chamber and through said light chamber when said vent valve is open. The blower means includes an electric driving motor and a fan impeller positioned within said growing chamber for circulating the air around said growing chamber, the fan impeller being drivingly connected to said electric motor. The light chamber comprises the top of said apparatus and is readily removable as a unit for providing access downwardly into said growing chamber for the removal of and care of plants therein. At one end the apparatus has a control chamber separate from said growing chamber; said top having louvres or vent holes at the control chamber end and at the opposite end; said top and said control chamber having aligned partition wall means spaced from a partition wall separating said control chamber and said growing chamber, and providing a fluid passage for outside environment air through said control chamber end louvres only, downwardly into said control chamber on the side of said aligned partition wall means remote from said partition wall separating said control chamber and said growing chamber and upwardly through said control chamber along the other side of said aligned partition wall means; said vent valve means being positioned in the partition wall separating said growing chamber and said control chamber for opening to the outside environment air on said other side of said aligned partition wall means; and fan means being provided for drawing air from adjacent said other side of said aligned partition wall means and discharging it upwardly into said top for travel therealong to exit through said opposite end louvres or vent holes.

Preferably also, the means for controlling the energising and de-energising of an electrically powered artificial light source is adapted to control a fluorescent light and an incandescent light and includes a thermostat to be responsive to the temperature within the plant growing chamber; and an electrical circuit for actuating the lights and having only the incandescent light in series with said thermostat for actuating said incandescent light when the temperature within said growing chamber falls below a predetermined temperature.

The electrical circuit may be arranged to connect the incandescent and fluorescent lights only in parallel; the means for controlling further including a manually controlled electrical switch to be in series with the incandescent light and a manually controlled electrical switch to be in series with the fluorescent light.

The means for controlling the artificial light source may further include a manually adjustable timer to be in series with the electrical unit comprising the fluorescent light and the incandescent light, the manually adjustable timer being in series with said thermostat and said manually controlled electrical switches.

The present invention also provides apparatus for supplying into a closed plant growing chamber which is at substantially atmospheric pressure a controlled quantity of carbon dioxide gas from a source of the gas under pressure, the apparatus comprising a control volume for the gas; pressure regulating means for regulating the pressure of gas supplied into said control volume from said source to a predetermined lower pressure greater than atmospheric pressure; and valve means operable to introduce the gas at said predetermined lower pressure into the control volume so as to fill the control volume with a predetermined quantity of the gas and to discharge that predetermined quantity of the gas from the control volume into the growing chamber.

The present invention still further provides a method of supplying a controlled quantity of carbon dioxide gas into a closed plant growing chamber for plant husbandry comprising introducing carbon dioxide gas from a source of carbon dioxide gas at a pressure greater than the gas pressure within the growing chamber into a control volume separate from the growing chamber at a predetermined, intermediate pressure so as to fill the control volume with a predetermined quantity of carbon dioxide gas and thereafter discharging said predetermined quantity of the carbon dioxide gas into the growing chamber.

The present invention still further provides a process for improved plant growth in a controlled environment in a substantially closed plant growing chamber employing a plant nutrient mixture of commercial plant fertiliser having added thereto Kinetin in a range from 1 over 2000 to 1 over 200 parts by weight and an algicide in the range from 1 over 1000 to 1 over 100 parts by weight, said process comprising supplying the improved plant nutrient mixture to plants within the growing chamber while, during predetermined intervals, maintaining the relative humidity in the growing chamber at high levels near saturation, and for each of said intervals, intro-

ducing carbon dioxide gas from a source of carbon dioxide gas at a pressure substantially greater than the gas pressure within the growing chamber into a control volume separate from the growing chamber at a predetermined intermediate pressure so as to fill the control volume with a predetermined quantity of carbon dioxide gas and thereafter discharging said predetermined quantity of the carbon dioxide gas into the growing chamber so as to raise the carbon dioxide gas content of the growing chamber to a level in excess of normal ambient value and at some value optimized for particular plants, and controlling the lighting and temperature conditions within the growing chamber to provide optimized growth conditions whereby the improved plant nutrient mixture fed to plants within the controlled environment maintains the stomatal pores of plants open so as to maximise carbon dioxide gas acceptance by the plants under the conditions where the high relative humidity of the controlled environment prevents excessive transpiration by the plants during the forced growth process.

A specific embodiment of the present invention will now be described by way of example with reference to the accompanying drawings wherein:—

Figure 1 is a perspective view of an apparatus according to the present invention showing plants within the growing chamber, the top in its sealed position and the various controls on the outside wall of the control chamber;

Figure 2 is a partial cross-sectional view taken along line II—II of Figure 1 showing the placement of the plant containers on the slats above the liquid nutrient which is supplied to the plants by wicks;

Figure 3 is a side elevation cross-sectional view taken along line III—III of Figure 1, particularly showing the flow of gasses within the apparatus when the vent is closed;

Figure 4 is a cross-sectional view similar to Figure 3, but with the vent open; and

Figure 5 shows a perspective partial cross-sectional view taken along line V—V of Figure 1 in conjunction with a somewhat schematic representation of the carbon dioxide circuit and the electrical control circuit.

Referring to the accompanying drawings, a controlled environment for plant husbandry is produced by the apparatus shown in Figure 1.

A plurality of containers 1, for example, flower pots having a central bottom hole, are filled with a suitable soil and the desired plant for placement on a plurality of movable wooden, plastics, metal, etc. boards or slats 2 within a closable growing chamber 3. The growing chamber is formed by a preferably removable front glass wall 4, stationary side glass wall 6, a rear wall 5 that may or may not be glass, a chamber dividing wall 7, a removable top section 8, and a tank-shaped bottom 9 that forms a liquid reservoir. The vertical walls 4—7 are held together in a rigid frame by means of angle-corner pieces 10 that are welded or otherwise rigidly secured to the fabricated sheet metal tank 9, with suitable sealing compounds and materials used to form air-tight joints. While 9 is described as comprising a tank, it is believed obvious that instead it can be designed to support tank-like removable trays, pans, buckets, cans etc. of liquid nutrient for a purpose to be described hereinafter.

As shown more clearly in Fig. 2, a framework of horizontally extending support members 11 are secured by welding or the like to the four vertical side walls 12 of the tank 9, to support thereon the movable transversely extending, parallel slats 2 as well as the bottom edges of at least some of the walls 4—7. Tank 9 is filled to a level preferably below the slats 2 with a liquid mixture of plant nutrient and water 13. For automatic feeding and watering of the plants, a fibrous wick 14 is arranged to extend from within the nutrient-water mixture in the tank 9 to the soil within associated container 1. For this purpose, a hole 15 is preferably provided in the bottom of each container 1 to allow passage of the wick 14. The slats 2 are loosely placed on the top of their support members 11 so that the slats 2 may be readily removed for cleaning of the tank 9, adding additional nutrient water mixture, and for providing just enough spacing to allow passage of the wicks 14 while covering the surface of the mixture 13 to the greatest extent for minimizing evaporation and algae formation.

On the far side of the chamber dividing wall 7, as shown in Fig. 1, there is provided a control chamber housing the electric and fluid controls for manually or automatically periodically supplying carbon dioxide to the growing chamber 3, for lighting the growing chamber with incandescent and fluorescent lights, and for supplying fresh air to the growing chamber. These features will be described in more detail with respect to the remaining figures, but are briefly mentioned here with respect to their relationship with the controls shown on the control panel 16.

A pressure gauge 17 is provided with a movable indicator and indicia 18 for indicating the parts per million of carbon dioxide added to the growing chamber 3, which ratio is controlled by means of a pressure regulating control knob 19. The automatic cycling of the apparatus is under the control of a timer 20, which is provided with a central adjusting knob 21 that may be pulled out to stop the timer or pushed in and rotated to set the correct time of day and start the timer; alternatively, an on-off switch 22 for the timer or for the entire apparatus may be provided. An On tab 23 and an Off tab 24

are provided on the timer to be set at the respective times for turning on and off the lights automatically; these tabs may be pushed in and rotated to a position where they are aligned with the desired numeral of the clock face carried with the knob 21. The timer may be of conventional construction. For manual overriding of the control for the lights, there is provided a manual electrical switch 25 that will light up when the fluorescent lights are on as called for by the timer 20; thereafter, this switch 25 may be pushed so that it will become dark and turn off the fluorescent lights independently of the timer 20. Similarly, the manual switch 26 is provided to control the energizing of and indicate the lighting of the incandescent lights for the growing chamber 3. While a specific design for the timing control switch has been described, it is to be understood that any suitable form of control for performing the switching functions noted might readily be employed as would be obvious to one skilled in the art.

In Figs. 1 and 3 it is seen that the top 8 is provided with a top wall 27, side wall 28 and bottom wall 29, which are all rigidly secured together to form a removable, artificial light chamber 30. A plurality of fluorescent lights 31 and incandescent lights (not shown) are operatively mounted within the light chamber 30, preferably by means of hangers attached to the top wall 27, so that the light may shine downwardly through the transparent bottom wall 29 into the growing chamber 3. For replacement of and serving the lights, the bottom wall 29 is constructed to be removable from the top 8. Also, a plurality of fluorescent light operating ballasts 32 are mounted within the chamber 30.

The control chamber 33 is formed by the top 8, chamber dividing wall 7, and suitable bottom and further side walls. Rigidly attached to the top 8, there is a partition wall portion 34 which aligns with and seals against a partition wall portion 35 that is rigid with the walls of the control chamber 33. At the right end as viewed in Fig. 3, that is, the control chamber end of the top 8, there is provided a plurality of louvers or air vent holes 36 that may be stationary or pivotably mounted to swing open under a differential of pressure.

During operation of the apparatus, cooling air continuously enters through the louvers or air vent holes 36 in the top 8, travels downwardly along the outside of the partition walls 34, 35 to the inlet of axial fan 37 for discharge upwardly and to the left into the light chamber 30. This movement of the cooling air, as shown by the arrows 38, will provide cooling for the various electrical controls on the control panel 16 and the electric motor 39, which drives the axial fan 37. As the cooling air moves to the left in the light chamber 30 as viewed in Figs. 3 and 4, it will cool the ballasts 32, the incandescent lights, and the fluorescent lights 31 before exiting to the left through louvers or air vent holes 40, which louvers 40 are opposite to but otherwise similar to the previously described louvers 36.

To provide circulation within the growing chamber 3 as shown by the arrows 41, an axial fan 42 is mounted within the growing chamber 3 to be driven by the motor 39.

Fresh outside environment air may be supplied to the growing chamber 3 by means of a vent valve 43, which is shown in its closed position in Fig. 3 and its open position in Fig. 4. An expansible chamber actuator 44 is spring-urged toward the right to close the vent valve 43 and is movable toward the left during expansion of its working chamber to open the valve 43. With the valve open as shown in Figure 4, the previously described cooling air circuit of Fig. 3 is modified only to the extent that cooling air now also enters the growing chamber 3 for circulation by the fan 42. That is, the growing chamber 3 is sealed with respect to the outside in Figure 3, but vented to the outside air in Fig. 4.

Further specific details of the vent valve 43 are shown in Fig. 5 wherein it is seen that the valve is formed from a rectangular hole 45 cut in the chamber dividing wall 7 and surrounded by a rectangular ring gasket 46, preferably a closed cell foamed elastomeric material such as rubber, which will engage the rigid sealing lip 47 of the movable valve portion 48, which movable valve portion 48 is rigidly provided with a nut 49 threadably receiving the piston rod 50 of the actuator 44. The actuator 44 is a conventional single acting, spring biased, piston-cylinder arrangement mounted by means of a bracket 51 that is welded or otherwise secured to the chamber dividing wall 7. As will be explained later, the vent valve 43 is operated by the carbon dioxide supplying system so that it will close when carbon dioxide is discharged into the growing chamber and will open when carbon dioxide is not supplied to the growing chamber.

Carbon dioxide is supplied to the growing chamber 3 from a pressurized source, particularly a pressurized container of liquid carbon dioxide 52. A commercially available quick disconnect fluid coupling is directly connected to the container 52 to facilitate changing containers. The discharge pressure of the carbon dioxide from the container 52 is determined by the pressure regulator 53, which is adjusted by means of the lever 54 and schematically shown mechanical linkage 55 extending to the control knob 19 on the control panel 16. The thus adjusted pressure is indicated on the pressure gauge 17 which is fluid connected to the regulator 53 by means of fluid line 56. A three-way valve 57 is normally biased in the counter clockwise direction by

means of a spring 58 to provide a direct connection between the regulator 53 and the T-fitting 59 that leads to a control volume chamber 60, so that carbon dioxide will fill the control volume chamber 60 to the pressure determined by the regulator 53 and shown on the pressure gauge 17. Simultaneously, pressurized carbon dioxide will be fed through the fluid line 61 to the working chamber of the actuator 44 to move the piston rod 50 to the left and thus open the vent valve 43. In this position of the three-way valve 57, no pressurized carbon dioxide will be fed through the fluid line 62.

When the lights are energized, the electric control circuit will simultaneously energize the solenoids 63 which will, through the linkage 64, rotate the three-way valve 57 in the clockwise direction to a position wherein the fluid line 62 will be only directly connected to the T-fitting 59 leading to the working chamber of the actuator 44 and the control volume chamber 60. In this position of the three-way valve, the predetermined quantity of carbon dioxide will be fed through the fluid line 62 into the growing chamber 3, which fluid line 62 is secured to the chamber dividing wall 7 by means of a suitable coupling 65. Thus, it is seen that the working chamber of the actuator 44 is vented to the substantially atmospheric pressure of the growing chamber 3 so that its internal spring (not shown) will move the piston rod 50 to the right to close the vent valve 43 and seal the growing chamber 3 for retention of the carbon dioxide within the growing chamber 3.

Since the volume occupied by the fluid line 61, T-shaped fitting 59, control volume chamber 60 and working chamber of the actuator 44 are known along with the effective volume of the growing chamber 3, the correlation between the pressure as indicated by the gauge 17 and the parts of carbon dioxide per million parts of gas within the growing chamber 3 is readily determined and incorporated in the indicia 18 associated with the pressure gauge 17, so that the parts per million may be read directly from the gauge 17 on the control panel 16. Thus, the control knob 19 will adjust the concentration of carbon dioxide. In addition, if a desired concentration cannot be obtained on the gauge 17 by means of manipulating the knob 19, this will indicate most usually that the carbon dioxide container 52 is empty.

The electrical control circuit for the apparatus as shown in Fig. 5 operates from a standard grounded three prong 120 volts, 60 cycle, AC, household outlet, with the power plug being schematically illustrated at 66. The ground line 67 of the plug is connected to the growing chamber case at 68, and the top case at 69. Electrical connection between the top 8 and the control chamber 33 is formed by means of a conventional quick disconnect coupling 70 that will be automatically disconnected when the top 8 is removed from the frame formed by the control chamber 33, vertical walls 4—7 and corner pieces 10; similarly, the electrical connection will be automatically made by the coupling 70 when the top is replaced.

Current is supplied by lines 71 and 72 for continuous operation of the motor 39 and the timer 20. As previously mentioned, the timer 20 is adjusted to turn on the lights for only a set period within each 24 hours, so that current will be supplied to the timer output 73 only within this period.

With current in line 73, the solenoid 63 is actuated to move the three-way valve 57 to a position for discharging the carbon dioxide from the control volume chamber 60 through fluid line 62 into the growing chamber 3 and simultaneously venting the actuator 44 to close the vent valve 43. Assuming that the manual switches 25, 26 are in their closed position, (their open position is illustrated in the drawing), current will be carried from the timer output 73 through switches 25, 26 and lines 74, 75 respectively, to the disconnect coupling 70 for respective connection to the top lines 76, 77, to respectively supply current to the parallel connected incandescent lamps 78 and the parallel connected ballasts 32. Current is returned from the incandescent lights 78 and ballasts 32 by means of the common line 79 through the disconnect coupling 70 to the power plug line 71. In a conventional manner the ballasts 32 will operate the fluorescent lights 31 when energized.

However, it is seen that a thermostat 80, which is mounted on the chamber dividing wall 7 to sense the temperature within the growing chamber 3, is connected in the line 75 to be in electrical series between the timer 20 and only the incandescent lights 78, that is, not the fluorescent lights. In this manner, the incandescent lights are used to control the temperature within the growing chamber 3. This is accomplished in that when the timer is calling for the lights to be on, the incandescent lights will be on only when the temperature is below a certain maximum pre-set temperature. Further control of the lights is seen from the series positioning of the manual switches 25, 26, that is, when the timer is calling for the lights to be on, the switch 25 may be manually actuated to turn off the fluorescent lights and/or the switch 26 may be manually actuated to turn off the incandescent light.

Most preferably, the overall size of the apparatus will be about 15 inches wide, 46 inches long and 22 inches high, with a growing chamber about 14 inches wide, 40 inches long and 16 inches high. Two 40 watt incandescent lights and four 30 watt fluorescent lights have been found to be most satisfactory.

The carbon dioxide system is constructed to provide any concentration within the range of 500 to 6000 parts per million above normal atmosphere and the timer can provide light periods of 1—23 hours each day.

The apparatus described is specifically designed for use in the home or other small plant growing operation. Operation is completely automatic, unless the user desires to use the manual over-rides for experimentation and the like.

The unit is turned on by plugging the power cord into a standard household three-prong grounded 120 volt AC outlet. In a like manner, the entire unit may be turned off by merely unplugging.

The top may be removed to fill the tank in the bottom with liquid nutrient, which would preferably have a balanced mixture of nitrogen, potassium, phosphorus in a normal 20-20-20 mix to provide the required micro-nutrients to sustain plant growth at the accelerated rate combined with algicide (copper sulfate) and Kinetin to promote growth in high carbon dioxide environment. The added Kinetin cause the stomatal pores of the leaf structure to open up for accepting the high concentration of carbon dioxide. Otherwise, pores normally would tend to close under increased carbon dioxide and temperature. The Kinetin further generates production of new chlorophyl, prevents degradation of existing chlorophyl, delays the onset of senescence in leaves, and promotes protein formation. A chelating agent may be added to keep the blend in solution.

The removable wooden slats are placed in position to provide for maximum coverage of the liquid nutrient and to prevent excessive evaporation during venting and algae formation, while allowing sufficient space between the slats to extend the wicks from the liquid nutrient to the plant containers. Preferably, plant containers with a bottom hole would be used. With the growing chamber sealed by the vent valve, the humidity will be close to saturation, which will prevent damage that would otherwise occur to the leaf structure under conditions of high carbon dioxide content and temperature. The adaptability of the present device is shown in that the slats may be removed not only to service the bottom of the tank but also to allow placement of plant containers directly within the nutrient solution, if desired, instead of on top of the slats. Thereafter, the top is reassembled on the apparatus (or alternatively a front, back or side opening is closed if access is provided in such manner) with automatic coupling between the lights and the electrical control circuit taking place along with sealing of the growing chamber.

The cycling of the lights is accomplished by pulling out the center knob of the timer and rotating the knob to indicate the correct time of day; thereafter, the knob is pushed back in to start the timer. The time at which the lights are to come on is set by pressing in the ON tab and rotating it to the desired time. Correspondingly, the time for the lights to be de-energized is set by pushing in the OFF tab and moving it to the desired time. The majority of plants will respond best to a light period of 14 to 16 hours. However, this light period may be set by the operator for any desired range for experimentation and to match the conditions within the apparatus to best grow a particular plant species. Except for experimentation, no further adjustment of the timer is necessary and the timer will automatically turn the lights On and Off at the desired times for continuous operation from day to day.

The automatic operation of the timer may be manually over-ridden if desired to provide particular effects. The fluorescent lights will produce a light strong in the blue wave lengths, which will grow short, bushy plants; the incandescent lights will provide a light strong in the red wave lengths, which will produce relatively tall and spindly plants. Normally, both fluorescent and incandescent lighting is desired since most plants require simulation of both the blue and red wave lengths of natural daylight. However for experimentation and special effects, the manual light switches on the control panel may be operated. During normal automatic operation of the apparatus, the two manual switches on the control panel will be illuminated to indicate that they are on when the timer is calling for light and will be dark to indicate that they are off when the timer has de-energized the lights. If it is desired to turn off either or both of the incandescent and fluorescent lights during the normal On period of the lights, it is merely necessary to push the corresponding switch or switches until they are darkened to indicate that their respective light is Off. The left hand switch on the control panel is used to manually control the fluorescent light, while the right hand switch on the panel is used to control the incandescent light.

The carbon dioxide concentration within the growing chamber may be controlled within a wide range to provide the desired effects with respect to plant growth. Normal range of operation is 500 to 2,000 parts of carbon dioxide per million parts of gas within the growing chamber above the normal atmosphere concentration of roughly 300 parts per million. The United States Department of Agriculture has made tests showing that a level of 1,000 to 2,500 parts per million will ordinarily result in optimum growth for most plants.

The desired concentration of carbon dioxide is obtained by turning the regulator knob on

the control panel until the control panel gauge needle registers with the desired parts per million setting on the indicia. Rotation of the regulator knob will correspondingly adjust the pressure regulator in the line between the carbon dioxide tank and the control volume for adjusting the pressure within the control volume when carbon dioxide gas is introduced into the control volume. Due to the automatic operation of the apparatus, carbon dioxide will thereafter be introduced into the growing chamber in the preset concentration each time that the lights are turned on, which will usually be once every day.

Here again, the apparatus is set up for completely independent automatic operation but may be adjusted within a wide range for special effects. The carbon dioxide concentration will to a great extent determine the foliage growth and its effect will be different for different types of plants. Higher levels of concentration should be used for plant with a great deal of foliage or for a crowded growing chamber, and correspondingly less concentrations of carbon dioxide should be used for plants with a small amount of foliage or when only a few plants are in the growing chamber. Ordinarily, carbon dioxide levels above 2,500 parts per million should not be used.

If for some reason, it is necessary to unseal the growing chamber while the lights are on, for example for the removal or tending of plants therein, it will be desirable to replenish the carbon dioxide that has escaped when the cover is off. This may be done by manipulating the timer on-off switch to turn off the timer and thereafter turning it back on after the cover has been replaced, which will have the effect of de-energizing and energizing, respectively, the solenoid controlling the three-way valve to correspondingly introduce carbon dioxide into the control volume and discharge it later into the growing chamber.

Normally, the thermostat will be set to provide for temperatures within the range of 90° F. to 95° F. when the lights are on, which setting may be adjusted to a known manner. Thus, the incandescent lights will be turned on automatically whenever the temperature drops below 90° F. The incandescent lights will be the prime source of heat for the growing chamber, because they provide a large amount of radiation in the far red region. The fluorescent lights will be unaffected by the thermostat operation. Excess heat from the lights will be removed by the environment air circulation as shown in Figure 3. The manual switches on the control panel may be used to over-ride this automatic operation with respect to either the fluorescent or the incandescent lights, without affecting the carbon dioxide cycle as determined by the timer. Even the automatic operation of the lights, vent and carbon dioxide may be altered by merely pulling out the center knob of the timer, without affecting the circulation of air as shown in Figure 4. As mentioned previously, the entire unit may be closed down disconnecting the plug from the standard outlet. The commercially available, quick connect and disconnect coupling provided for the carbon dioxide pressurized cylinder facilitates easy and fail-safe replacement of the CO_2 cylinder. Normally, the CO_2 cylinder will be replaced only about every six months.

During the growth process, flow of water takes up the plant structure (from the soil through the roots, stem and leaves to the atmospheric air) and carries along the elements necessary for healthy growth from the nutrients in the soil and the nutrients added to the soil in the form of fertilizer chemicals The adsorption of CO_2 from the surrounding air, and the loss of water from the plant to the surrounding air occurs through the stomatal pores located on the surface of the leaves. The stomatal pores have the ability to open and close to admit more or less CO_2, or concurrently to transpire more or less water. Stomata are known to open and close in response to the level of CO_2 in the surrounding environment. CO_2 levels below normal (below about 300 parts per million) (ppm) cause the stomata to open, whereas CO_2 levels above normal cause the stomata to close. A closed, or partially closed stomata causes an increased resistance to the passage of CO_2 into the plants, thus reducing the full benefit to be derived from growing plants under increased CO_2 levels in the controlled environment. The improved process made available by the invention combats the natural tendency for the plants to close its stomata under high CO_2 concentrations in the gaseous atmosphere by use of the added hormone chemical that is part of the recommended nutrient preparation.

The recommended nutrient preparation is a special material containing the normally required nutrients of nitrogen-potassium-phosphorus (N-K-P) in for example a 20-20-20 mix or some other suitable mix such as 10-10-10 with an added algicide such as copper sulfate to reduce algae formation under the intense artificial lighting and high humidity conditions of the controlled environment, and with added Kinetin to cause the plant to open its stomatal pores in order to obtain full benefit from the concentration of CO_2 in the atmosphere of the controlled environment.

A recommended formulation for the improved plant nutrient mixture is as follows:

Commercial plant food (N-K-P), (20-20-20)	2 grams
Kinetin	2.5 milligrams
Copper sulfate	4.0 milligrams

This mixture is dissolved in one gallon of water and used to feed plants grown in the controlled environment at elevated CO_2 levels. The copper sulfate is added as an algicide to minimize the growth of algae at the high humidity and high light intensity found in the controlled environment, and is quite successful.

Tests were made with the above formulation in the controlled environment herein described, at high CO_2 levels using the improved nutrients with algicide in connection with certain test plants, and using only commercial plant food with algicide on other control plants. The results of the tests are set forth below.

		Control at High CO_2	Test at High CO_2 (Kinetin Added)	Ratio Test/ Control
Wet weight, grams	9 Day Results	.6397	1.0106	1.55
Dry weight, grams		.0473	.0846	1.79
Dry weight/wet weight %		7.4	8.4	1.15

The plants fed with the improved nutrient were demonstrated to be 55% heavier, had 79% greater dry weight and had a 15% greater dry weight/wet weight than did the plants which were not supplied with the improved nutrient.

WHAT WE CLAIM IS:—

1. Apparatus for providing a controlled environment for plant husbandry including a closable plant growing chamber; a separate control volume for a gas which is to be introduced into the growing chamber; pressure regulating means for regulating the pressure of the gas, which is to be supplied from a source of the gas at pressure higher than the pressure in the growing chamber, to an intermediate, predetermined pressure; and valve means operable to introduce the gas at said intermediate, predetermined pressure into the control volume so as to fill the control volume with a predetermined quantity of the gas and to discharge that predetermined quantity of the gas from the control volume into the growing chamber.

2. The apparatus of Claim 1 further including a pressure gauge which measures said predetermined, intermediate pressure; said pressure regulating means being adjustable to adjust said predetermined, intermediate pressure and said pressure gauge being calibrated to indicate the parts of the gas in the control volume per million parts of gas in the growing chamber.

3. The apparatus of Claims 1 or 2, further including means for controlling the energising and de-energising of an electrically powered artificial light source for producing light within the growing chamber.

4. The apparatus of Claim 3 further including circuit means for operating said valve means in response to said light controlling means being in a state de-energising the light source to introduce said gas into said control volume and further operating said valve means in response to said light controlling means being in a state energising the light source for discharging said gas from said control volume into the growing chamber.

5. The apparatus of Claim 4 wherein said circuit means includes solenoid means in circuit with said means for controlling the energising and de-energising of said light source and mechanically drivingly connected to said valve means.

6. The apparatus of any preceding Claim further including a vent valve for admitting outside environment air into said growing chamber when open and having a closed position for effectively sealing said growing chamber from the outside environment air; and automatic actuator means which opens said vent valve in response to said valve means introducing said gas into said control volume and which closes said vent valve in response to said valve means discharging said gas into said growing chamber from said control volume.

7. The apparatus of Claim 6 wherein said actuator means includes a power cylinder means spring biased to close said vent valve and having a working chamber expansible by gas under pressure to open said vent valve; and said working chamber forms part of said control volume.

8. The apparatus of Claim 6 or 7 further including: a light chamber for the artificial light source fluid separate from but in light communication with the growing chamber; and blower means for circulating outside environment air through said light chamber when said vent valve is closed and for circulating outside environment air through said vent valve into said growing chamber and through said light chamber when said vent valve is open.

9. The apparatus of Claim 8 wherein said blower means includes an electric driving motor and a fan impeller positioned within said growing chamber for circulating the air around said growing chamber, the fan impeller being drivingly connected to said electric motor.

10. The apparatus of Claim 8 or 9 wherein said light chamber comprises the top of said apparatus and is readily removable as a unit for providing access downwardly into said growing chamber for the removal of and care of plants therein.

11. The apparatus of Claim 10 further including: a control chamber at one end, separate from said growing chamber; said top having louvres or vent holes at the control chamber end and at the opposite end; said top and said control chamber having aligned partition wall means spaced from a partition wall separating said control chamber and said growing chamber, and providing a fluid passage for outside environment air through said control chamber end louvres only, downwardly into said control chamber on the side of said aligned partition wall means remote from said partition wall separating said control chamber and said growing chamber and upwardly through said control chamber along the other side of said aligned partition wall means; said vent valve means being positioned in the partition wall separating said growing chamber and said control chamber for opening to the outside environment air on said other side of said aligned partition wall means; and fan means being provided for drawing air from adjacent said other side of said aligned partition wall means and discharging it upwardly into said top for travel therealong to exit through said opposite end louvres or vent holes.

12. The apparatus of Claim 11 when Claim 10 is dependent upon Claim 9 wherein said fan means comprises said electric motor which is housed within said control chamber in said fluid passage for outside environment air; said motor having a shaft extending through said partition wall separating said control chamber and said growing chamber and mounting said fan impeller positioned within said growing chamber.

13. The apparatus of Claim 3, 4 or 5 or any one of Claims 6 to 12 when Claim 6 is directly or indirectly appendant to Claim 4, wherein the means for controlling the energising and de-energising of an electrically powered artificial light source is adapted to control a fluorescent light and an incandescent light and includes a thermostat to be responsive to the temperature within the plant growing chamber; and an electrical circuit for actuating the lights and having only the incandescent light in series with said thermostat for actuating said incandescent light when the temperature within said growing chamber falls below a predetermined temperature.

14. The apparatus of Claim 14 wherein said electrical circuit is arranged to connect the incandescent and fluorescent lights only in parallel; the means for controlling further including a manually controlled electrical switch to be in series with the incandescent light and a manually controlled electrical switch to be in series with the fluorescent light.

15. The apparatus of Claim 14 wherein the means for controlling further includes a manually adjustable timer to be in series with the electrical unit comprising the fluorescent light and the incandescent light, the manually adjustable timer being in series with said thermostat and said manually controlled electrical switches.

16. The apparatus of any preceding Claim wherein said growing chamber includes means forming a reservoir for containing liquid nutrient at the bottom thereof; supports on opposite sides of said means forming a reservoir and a plurality of parallel removable slats received on said supports and extending between said opposite sides for holding thereon a plurality of plant containers while allowing wick communication between the containers and the nutrient within the reservoir.

17. A method of supplying a controlled quantity of carbon dioxide gas into a closed plant growing chamber for plant husbandry comprising introducing carbon dioxide gas from a source of carbon dioxide gas at a pressure greater than the gas pressure within the growing chamber into a control volume separate from the growing chamber at a predetermined, intermediate pressure so as to fill the control volume with a predetermined quantity of carbon dioxide gas and thereafter discharging said predetermined quantity of the carbon dioxide gas into the growing chamber.

18. A method as claimed in Claim 17 including adjusting said predetermined intermediate pressure so as to obtain a concentration of carbon dioxide gas in said growing chamber in excess of 500 parts per million of carbon dioxide gas above the normal atmospheric level.

19. A process for improved plant growth in a controlled environment in a substantially closed plant growing chamber employing a plant nutrient mixture of commercial plant fertiliser having added thereto Kinetin in a range from 1 over 2000 to 1 over 200 parts by weight and an algicide in the range from 1 over 1000 to 1 over 100 parts by weight, said process comprising supplying the improved plant nutrient mixture to plants within the growing chamber while, during predetermined intervals, maintaining the relative humidity in the growing chamber at high levels near saturation, and for each of said intervals, introducing carbon dioxide gas from a source of carbon dioxide gas at a pressure substantially greater than the gas pressure within the growing chamber into a control volume separate from the growing chamber at a predetermined intermediate pressure so as to fill the control volume with a predetermined quantity of carbon dioxide gas and

thereafter discharging said predetermined quantity of the carbon dioxide gas into the growing chamber so as to raise the carbon dioxide content of the growing chamber to a level in excess of normal ambient value and at some value optimized for particular plants, and controlling the lighting and temperature conditions within the growing chamber to provide optimized growth conditions whereby the improved plant nutrient mixture fed to plants within the controlled environment maintains the stomatal pores of plants open so as to maximise carbon dioxide acceptance by the plants under the conditions where the high relative humidity of the controlled environment prevents excessive transpiration by the plants during the forced growth process.

20. A process according to Claim 19 further including venting the growing chamber to the atmosphere during periods of darkness intervening said predetermined intervals so as to permit the plants to breathe normally under normal ambient conditions where photosynthesis is not occurring as it would occur in the presence of light.

21. A process according to Claim 20 wherein the improved plant nutrient mixture is supplied to the plants in liquid form through wick feeding from a suitable reservoir.

22. A process according to Claim 19, 20 or 21 wherein the improved plant nutrient mixture is used in liquid form at a total nutrient-Kinetin-algicide mixture concentration of from 1/2 grams per gallon of water to 10 grams per gallon of water.

23. Apparatus for supplying into a closed plant growing chamber which is at substantially atmospheric pressure a controlled quantity of carbon dioxide gas from a source of the gas under pressure, the apparatus comprising a control volume for the gas; pressure regulating means for regulating the pressure of the gas supplied into said control volume from said source to a predetermined lower pressure greater than atmospheric pressure; and valve means operable to introduce the gas at said predetermined lower pressure into the control volume so as to fill the control volume with a predetermined quantity of the gas and to discharge that predetermined quantity of the gas from the control volume into the growing chamber.

24. Apparatus for providing a controlled environment for plant husbandry substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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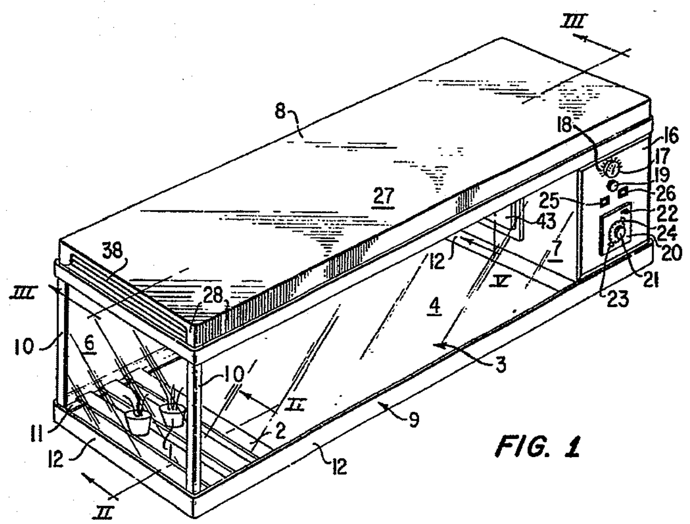
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FIG. 1

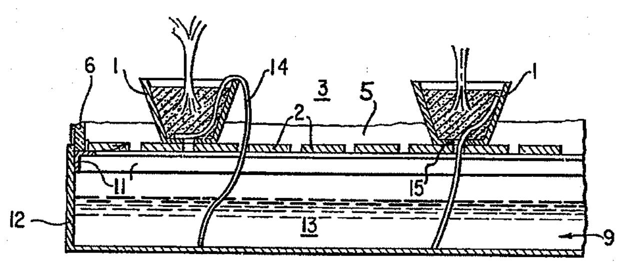
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FIG. 2

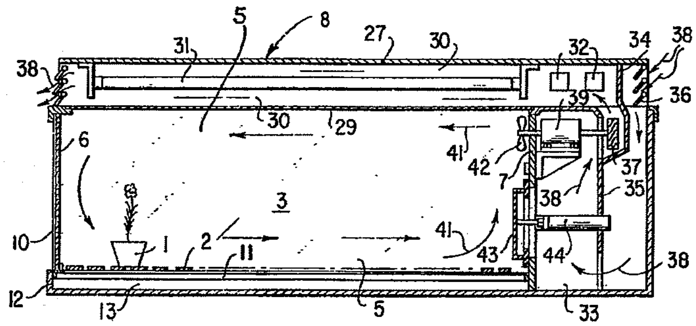
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FIG. 3

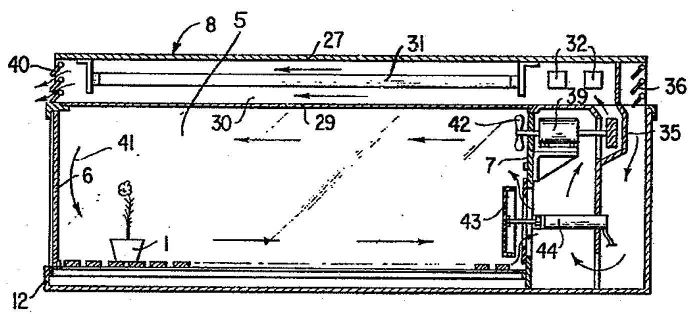
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FIG. 4

1349001 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

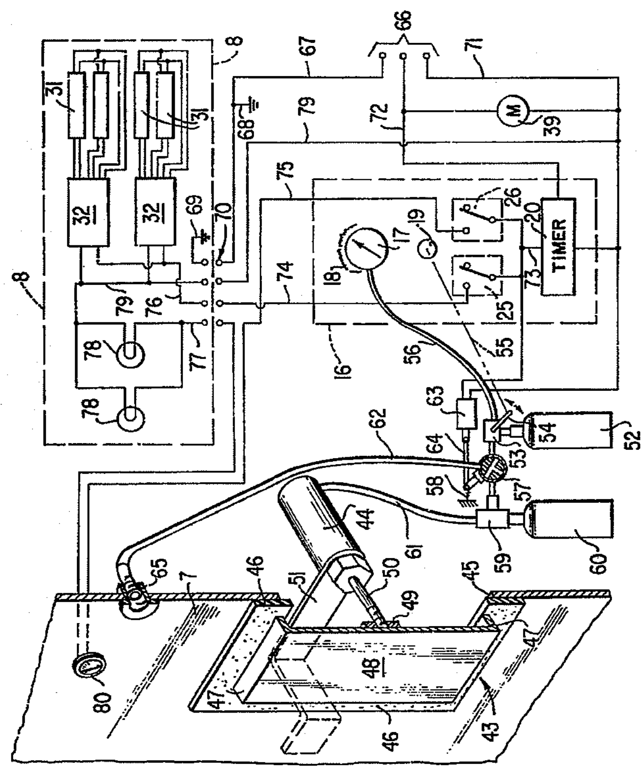

FIG. 5